$\Theta^+(1540)$ Search with CLAS
$\gamma d \rightarrow p K^0 K^- (p)$

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CLAS Collaboration

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Outline

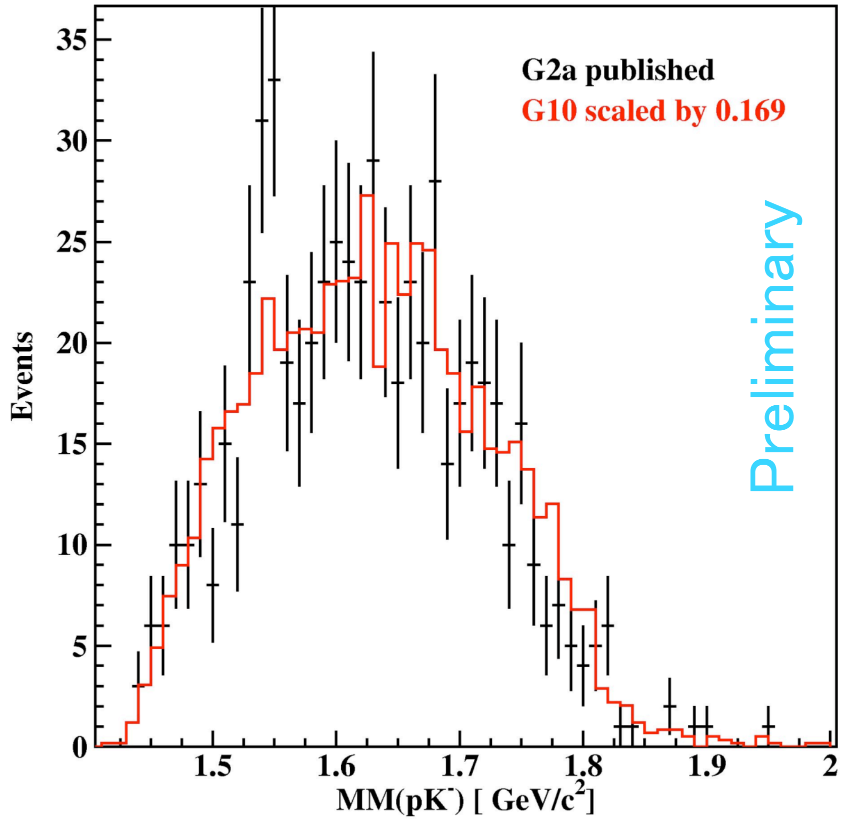
- Motivation
- Event Identification
- Background Simulation

Hall B Analyses

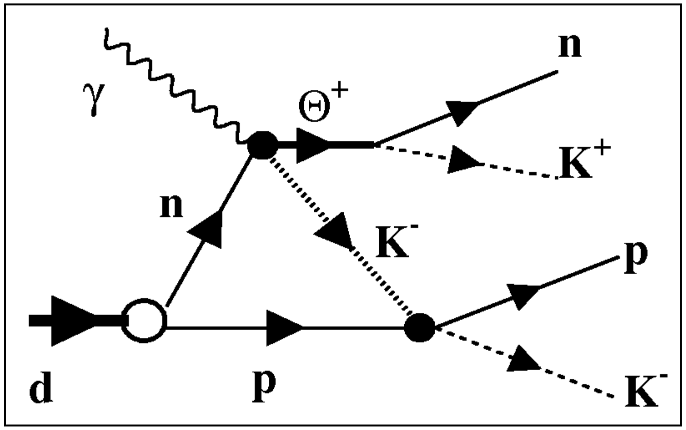
3 new, high statistic data sets

- Θ^+ (g10)
  - $\gamma + d \rightarrow \Theta^+ + K^- + (p) \rightarrow n + K^+ + K^- + (p)$
  - $\gamma + d \rightarrow \Theta^+ + K^- + p \rightarrow n + K^+ + K^- + p$
  - $\gamma + d \rightarrow \Theta^+ + K^- + (p) \rightarrow p + K^0 + K^- + (p) \rightarrow p + \pi^+ + \pi^- + K^- + (p)$
  - $\gamma + d \rightarrow \Theta^+ + \Lambda^0 \rightarrow n + K^+ + p + \pi^-$
- Θ^+ (g11)
  - $\gamma + p \rightarrow \Theta^+ + \overline{K^0} \rightarrow n + K^+ + \pi^+ + \pi^-$
  - $\gamma + p \rightarrow \Theta^+ + K^- + \pi^+ \rightarrow n + K^+ + K^- + \pi^+$
- Ξ_5^{--} (eg3)
  - $\gamma + n\ (p) \rightarrow K^+ + K^+ + \Xi_5^{--}$

CLAS $\gamma d \rightarrow \Theta^+ K^- p$

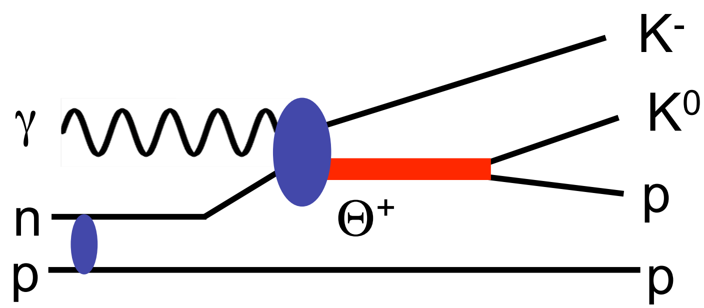


- Two distributions statistically consistent with each other:
  - 26% c.l. for null hypothesis from the Kolmogorov test (two histograms are compatible).
  - Reduced χ^2**=1.15** for the fit in the mass range from 1.47 to 1.8 GeV/c^2



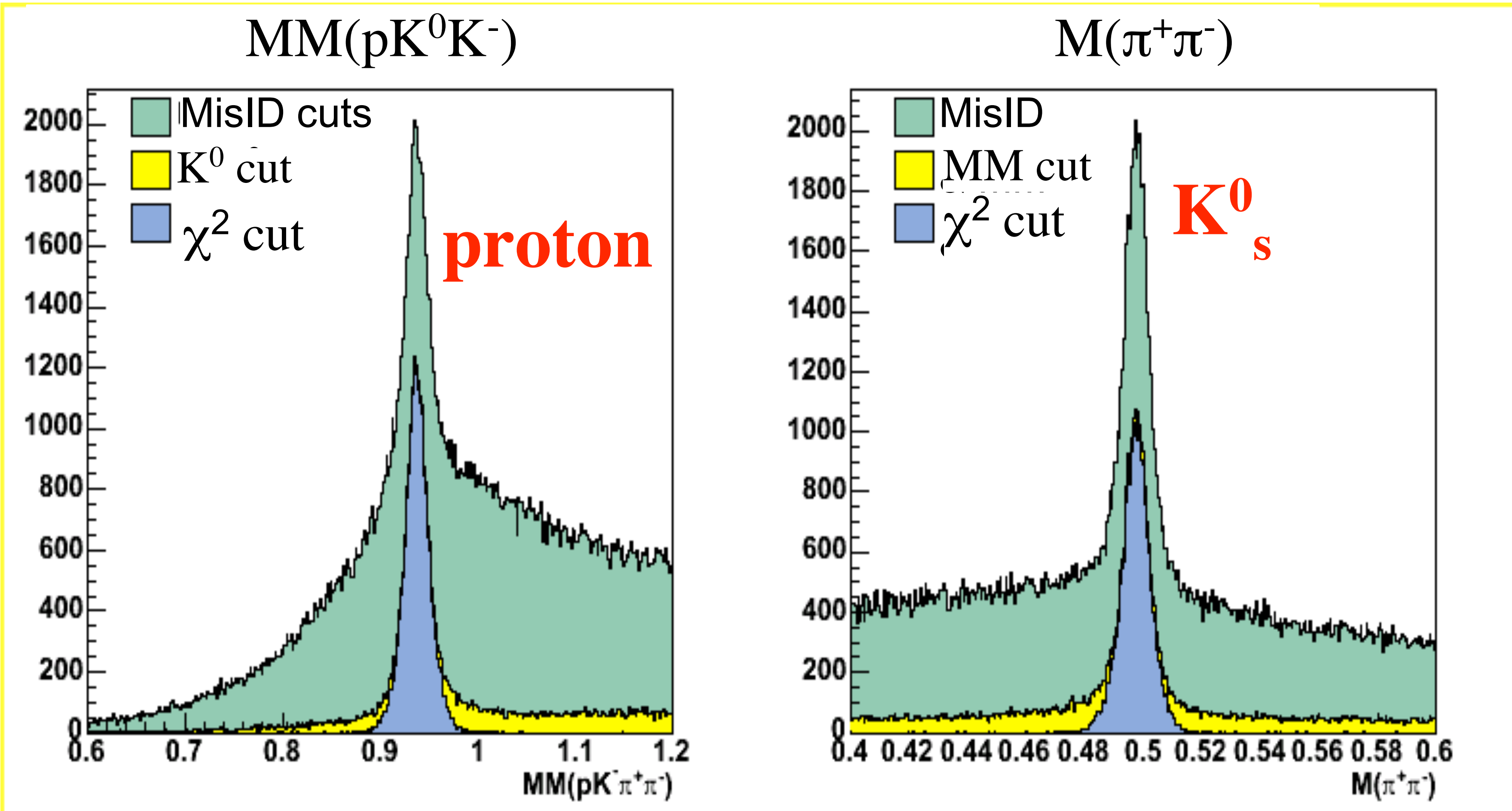
- With Fermi momentum being the only source of an energetic spectator proton, the cross section upper limit is **20nb**.
- If we assume a more sophisticated model for an energetic spectator and take the $\Lambda(1520)$ production as a guide, the cross section upper limit is **4-5 nb** (model dependent).

CLAS $\gamma d \rightarrow \Theta^+ K^- p$



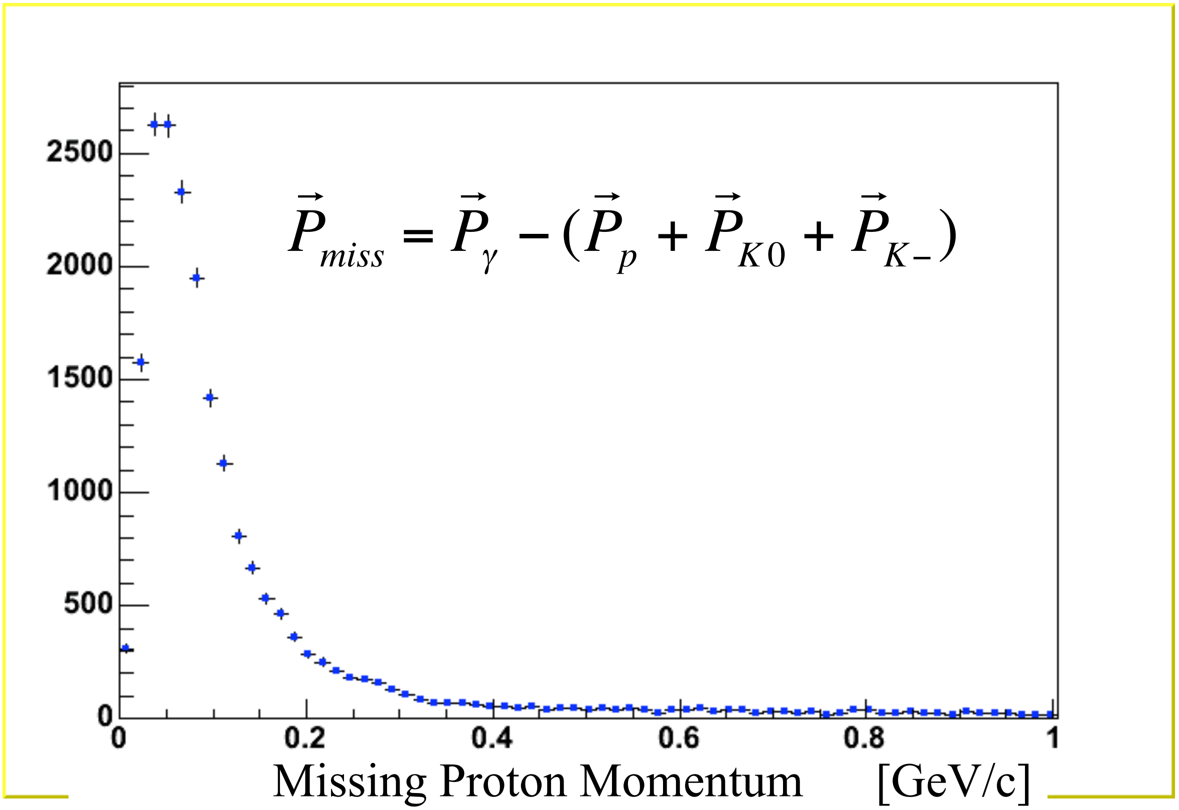
- Complementary to nK^+K^-p channel
- Exclusive Measurement
  - Undetected proton is considered a spectator
  - Reconstruct K^0 from decay to $\pi^+\pi^-$
- pK^0 strangeness defined by detected K^-

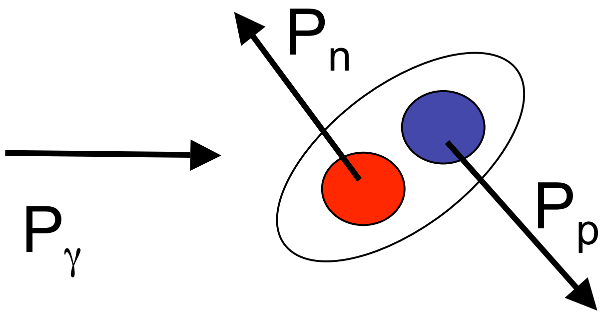
Identifying $\gamma d \rightarrow pK^- K^0 (p)$



Yield ~22,000

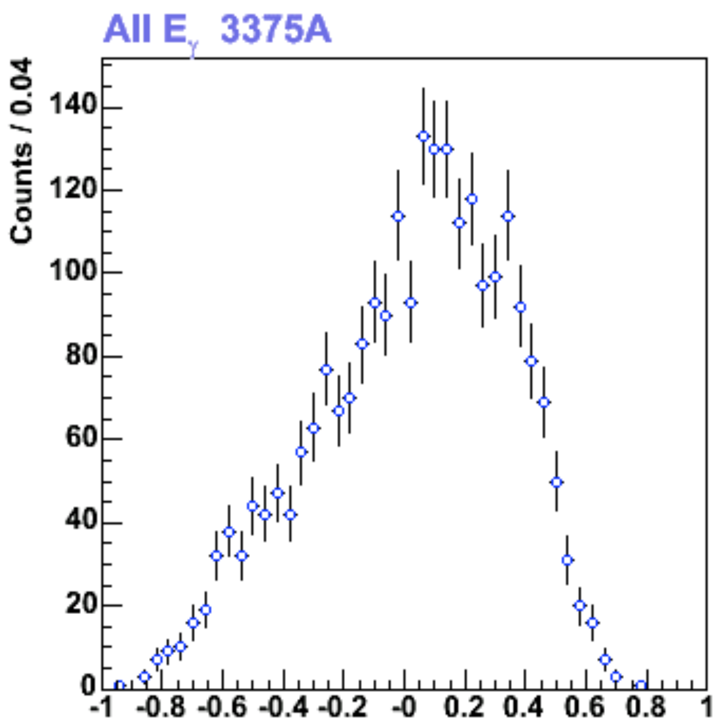
Missing Proton Momentum



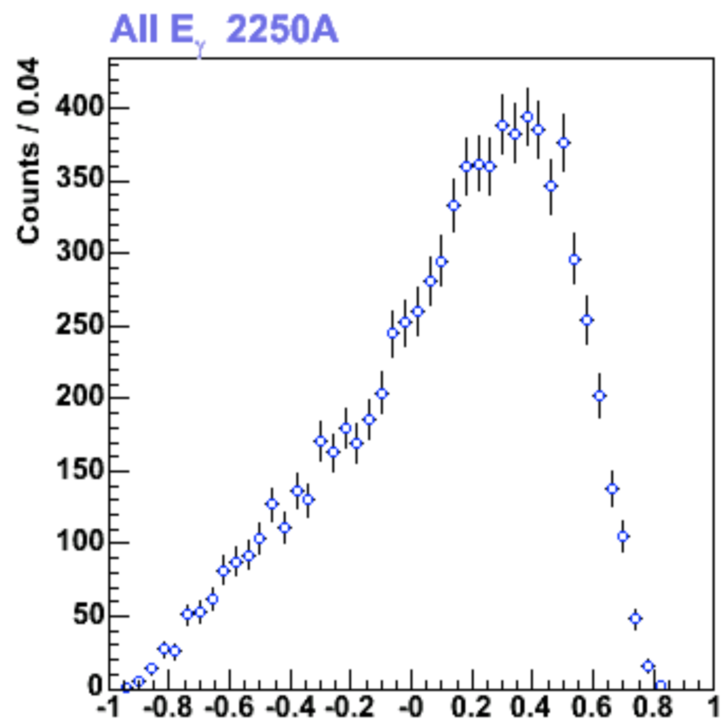


Momentum Distribution consistent with deuteron distribution up to ~ 200 MeV/c

K^- Angular Coverage



$K^- \cos(\theta_{cm})$



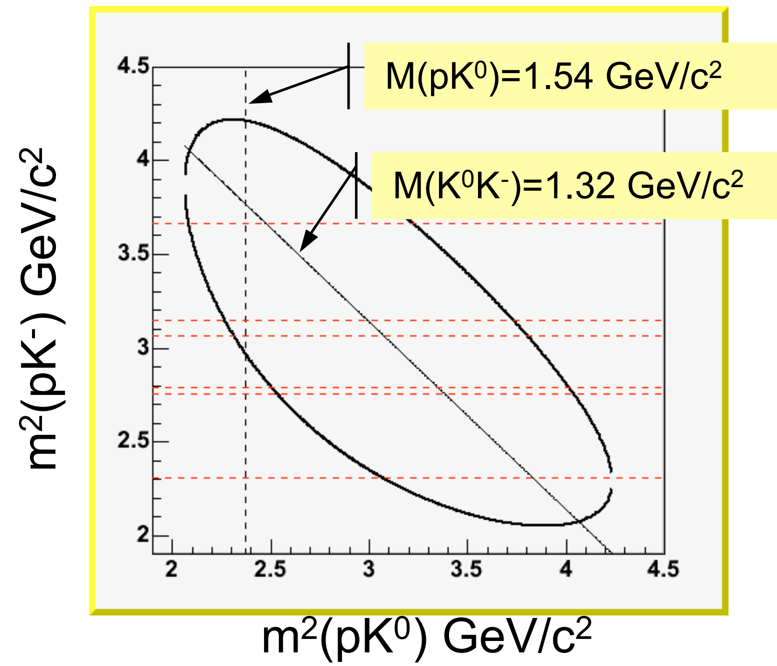
$K^- \cos(\theta_{cm})$

CLAS provides wide coverage except at most forward angles

Physics Backgrounds $\gamma d \rightarrow p\pi^+\pi^- K^-$ (p)

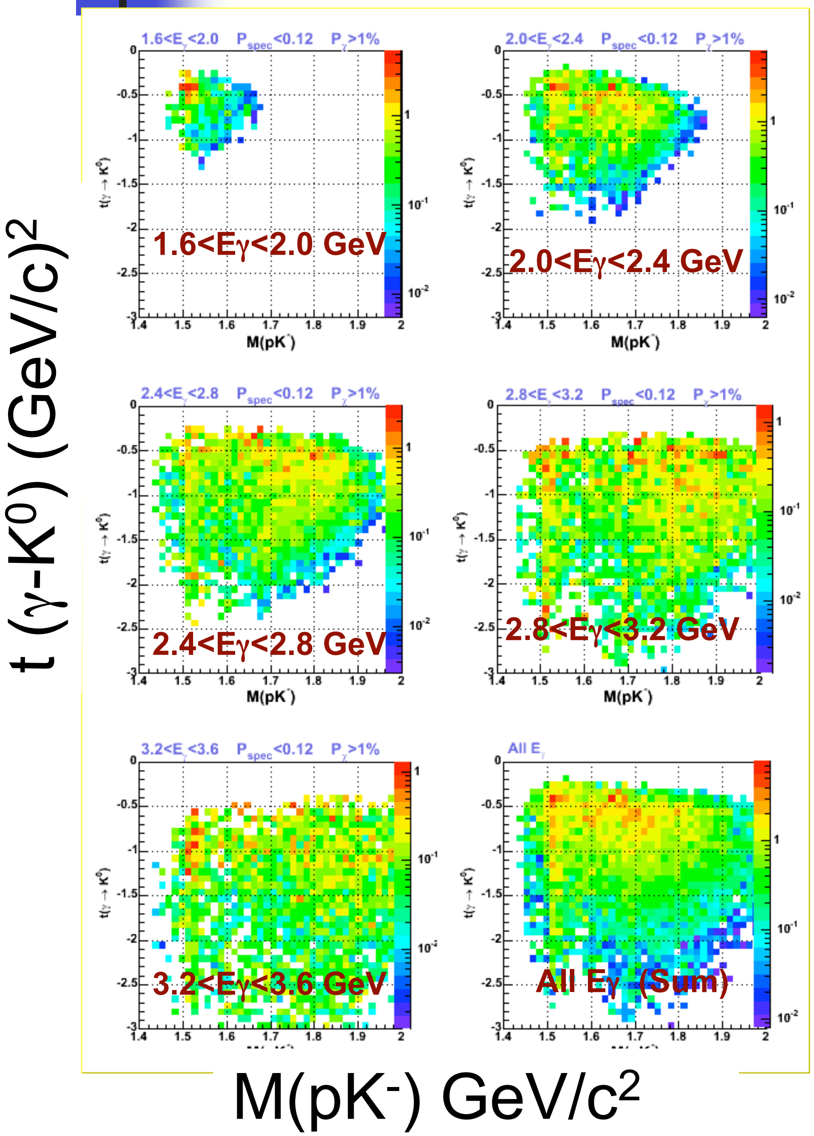
Channel is rich with hadronic processes

- Direct access to physics background
  - Populate Baryons: Λ^* and Σ^*
  - Mesons: $a_0(980)$,$a_2(1320)$, $\rho_3(1690)$
- Goal: Develop good description of background contribution
  - Prerequisite for understanding mass projections

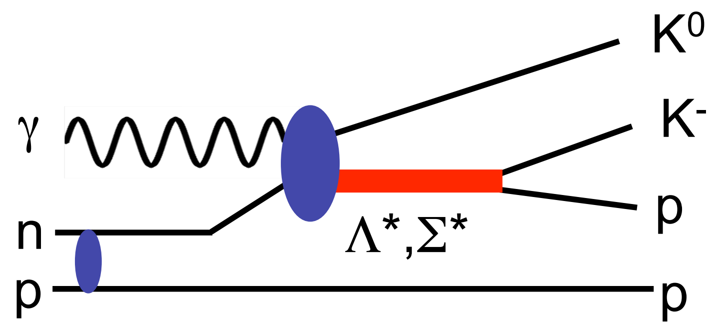


Dzierba *et al.*, Phys. Rev. D **69**, 051901 (2004).

Hyperon t-dependence

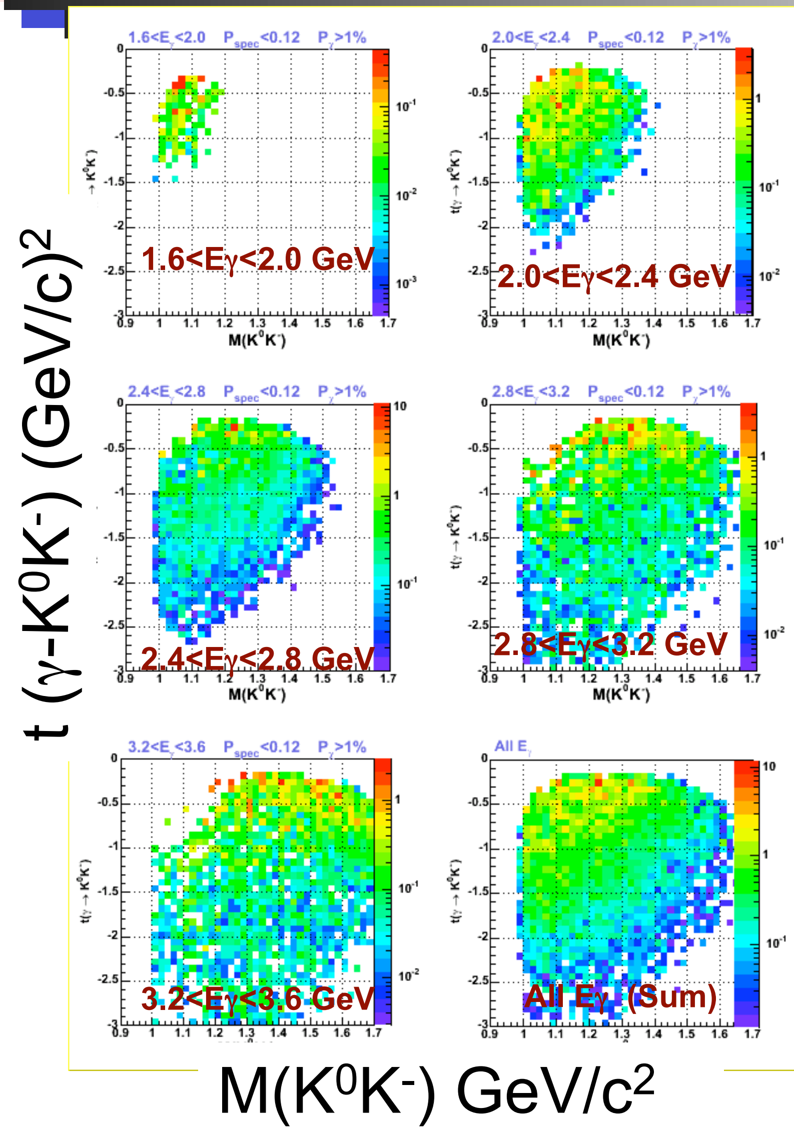


Λ(1520), Λ(1690), Λ(1820), Λ(1830), Λ(1890), Σ(1775)

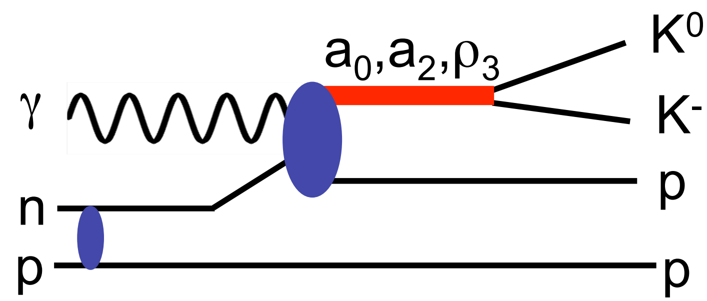


Λ(1520) production consistent with slope of ~3

Meson t-dependence



$a_0(980)$, $a_2(1320)$, $\rho_3(1690)$



Contributions increase with increasing photon energy

Meson and Hyperon Simulation

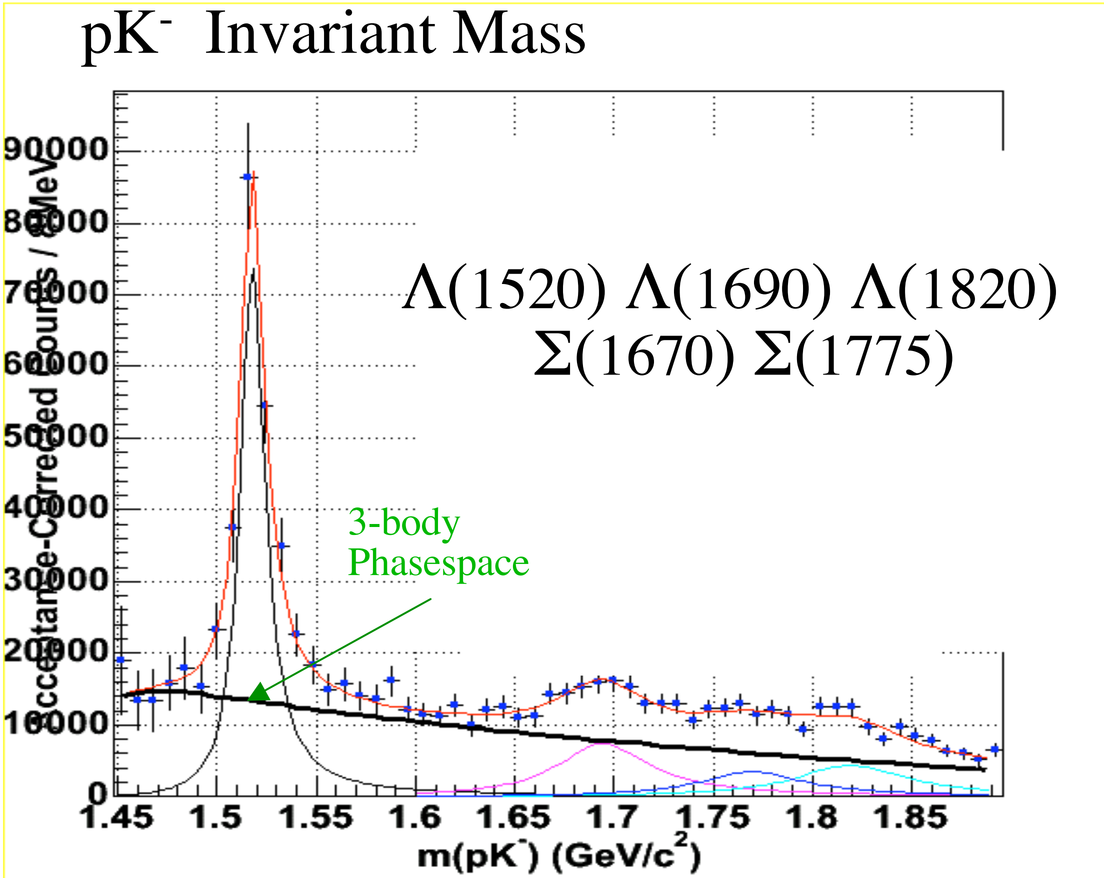
- Monte Carlo Simulation
  - Produce accurate acceptance
  - Background shape for m(pK^0) spectrum
- Sample Nucleon Momentum Distribution
  - Begin with 3-body phase space
  - Bonn Wave Function
- Compute Relativistic Breit Wigner Amplitudes
  - s-dependant coefficients
  - Exponential t-dependance

$$A(s,t,m,\theta_h,\phi_h) = C(s)\frac{m_0\Gamma}{m_0^2 - m^2 - im_0\Gamma}e^{Bt}Y_l^m(\theta_h,\phi_h) \qquad \Gamma = \left(\frac{m_0}{m}\right)\left(\frac{q}{q_0}\right)\Gamma_0$$

- Weight events by sum of all amplitudes (squared)
  - Allows for interferences

Challenge - determine C(s)

$\gamma n \rightarrow Y^{*}K^{0}$ Yield Estimates



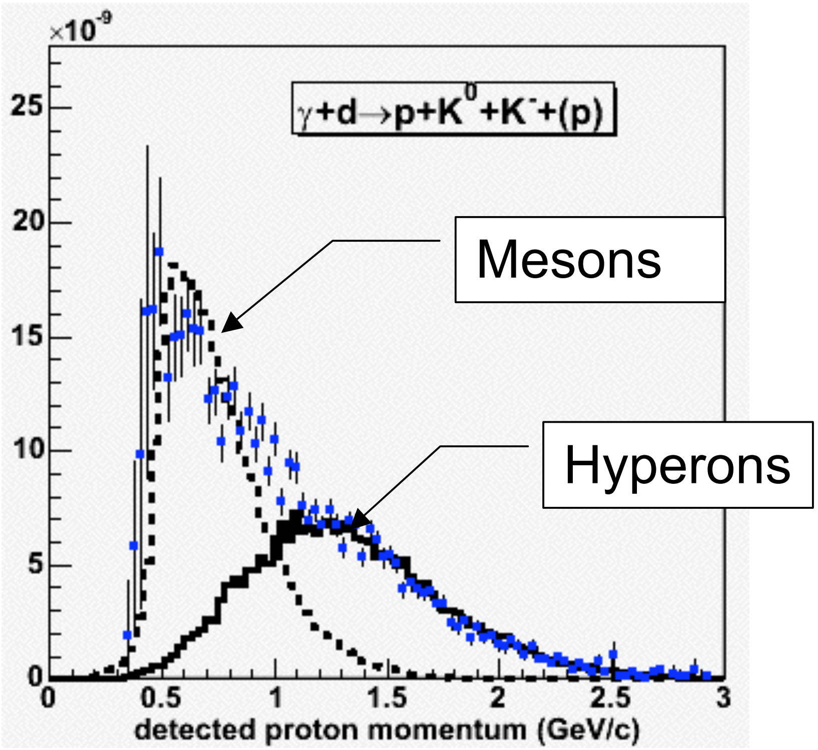
Iterative procedure

1st step:

Phase space acceptance

Fit BW's in energy bins

Meson/Hyperon Simulation



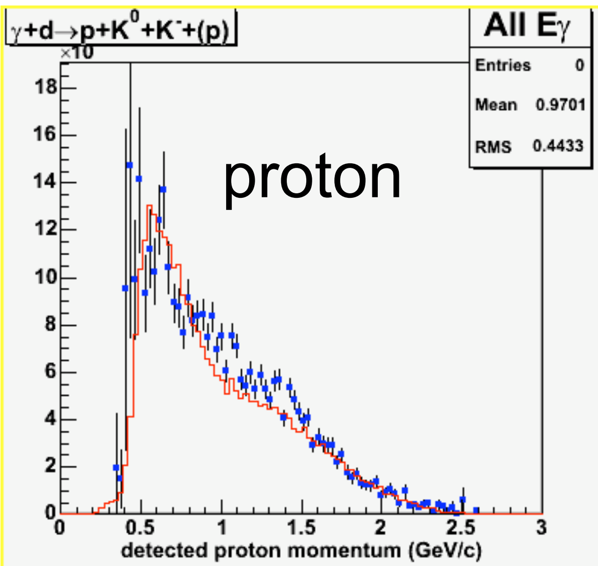
Blue points - CLAS data: acceptance corrected and flux normalized

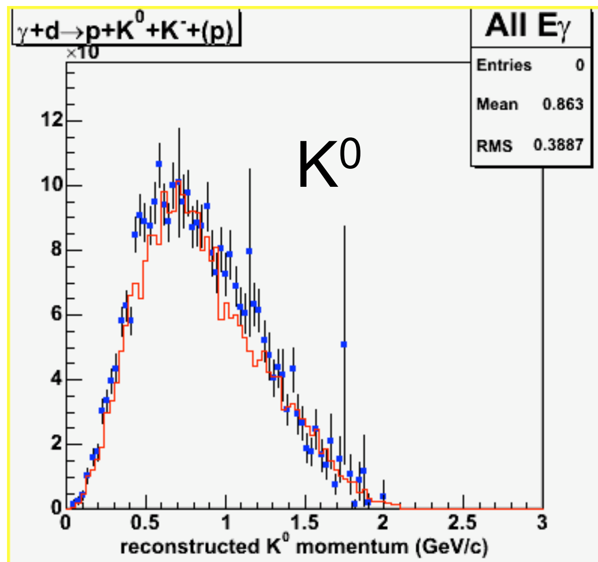
- Mesons forward produced
  - Low momentum proton
- Hyperon decay results in fast proton
- Use relative contributions to estimate meson amplitudes

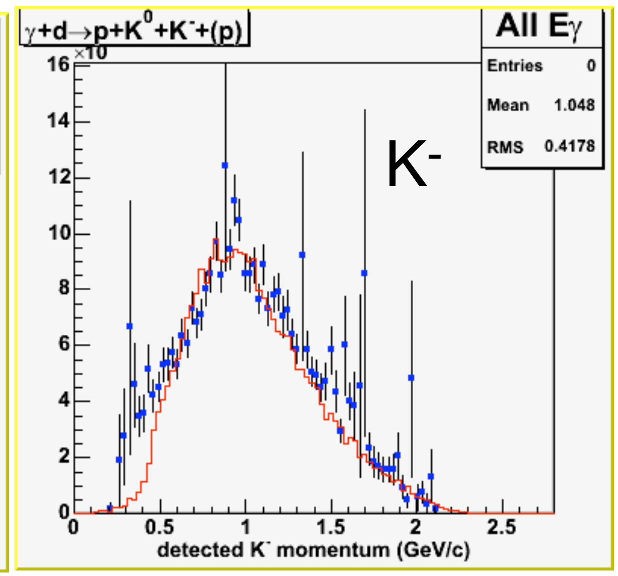
Momentum Distributions

Blue points - acceptance corrected data

Red Histogram - Monte Carlo calculation







Full Simulation with estimated coefficients

Good description over entire range of kinematics

pK⁻ Mass Distributions

M(pK⁻)

1.6<Eγ<2.0 GeV

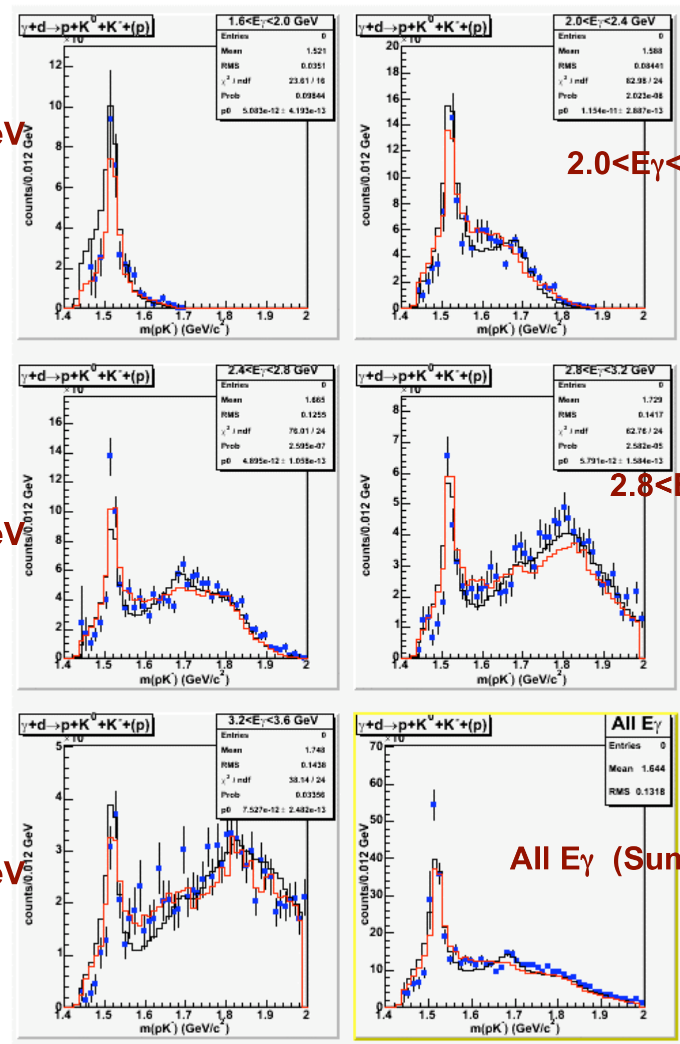
2.0<Eγ<2.4 GeV

2.4<Eγ<2.8 GeV

2.8<Eγ<3.2 GeV

3.2<Eγ<3.6 GeV

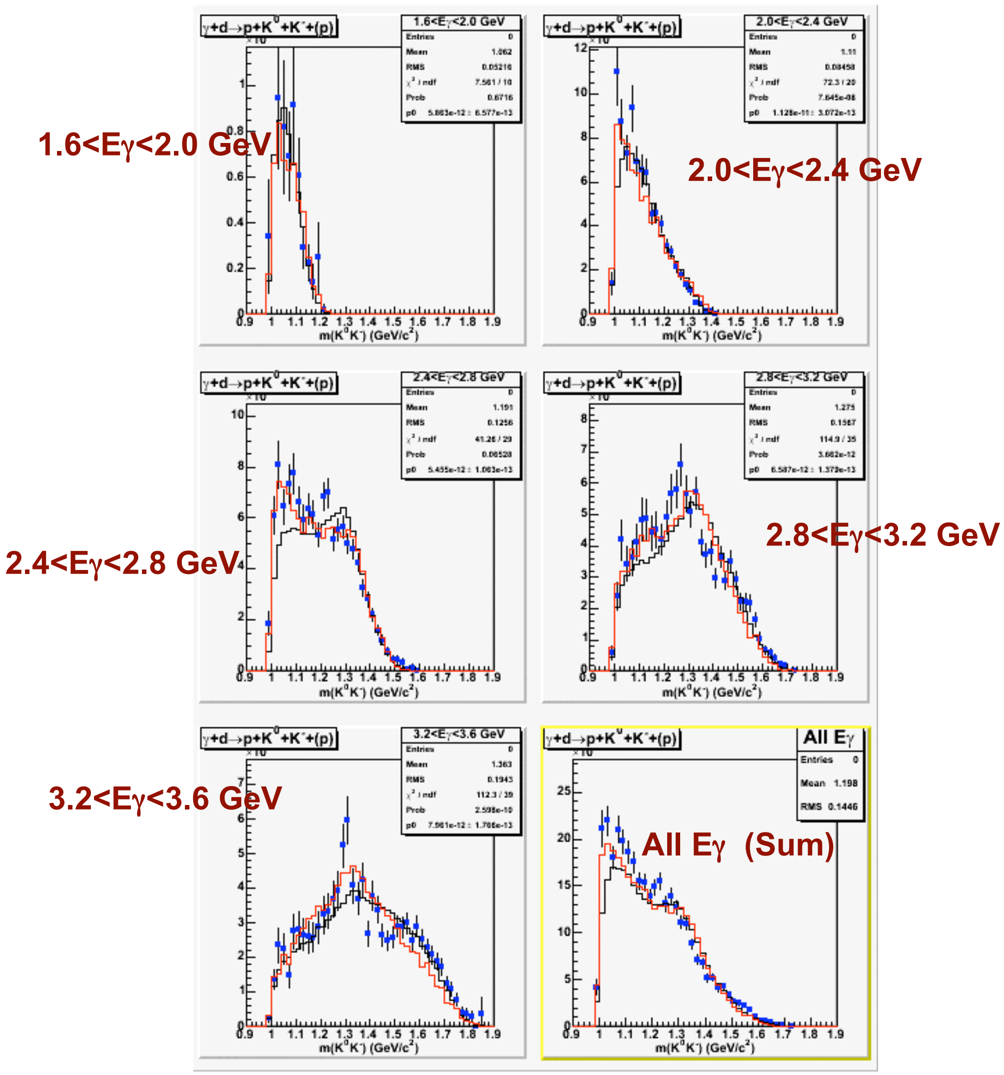
All Eγ (Sum)



Phase space changes significantly as photon energy increases

K^0K^- Mass Distributions

$M(K^0K^-)$



See enhancements at low mass due to $a_0(980)$

Structure from heavy mesons evident for

$E\gamma > 2.4$ GeV

Summary

- $\gamma d \rightarrow pK^0K^-(p)$ search part of larger CLAS effort.
  - Quasi-free, no FSI, well defined strangeness

- Before drawing conclusions and releasing results in this pentaquark search channel, it is important to understand the background.

- MC model – resonant mesons and hyperons fit the data fairly well over wide range of kinematics with estimated parameters.

- In progress: Implementation of un-binned log-likelihood fit of the resonant amplitudes.